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A forecasting model for emergence and flight pattern of the overwintering generation of *Chilo suppressalis* (Lepidoptera: Pyralidae) based on pheromone trap catches and degree-days in northeastern China

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Abstract: A linear forecasting model to monitor the spring emergence and flight pattern of the overwintering generation of the rice stem borer, *Chilo suppressalis* (Walker), in northeastern China was developed. The model is based on the correlation between the pheromone trap catches and corresponding degree-days (DDs) calculated from 1 March above the threshold of 12.9℃ in Liuhe, Jilin in 1999 – 2000. Overwintering adults generally begin to appear in Liuhe rice fields after 126.995 cumulative DDs. The DD accumulations from 1 March corresponding to the capture of 10%, 50% and 90% of all male moths throughout the flight season were 238.323, 339.418 and 483.398, respectively. The comparison of the predicted results with the observed data in three years (2002 – 2004) in Changchun city verified the reliability of the log-probit line forecasting model, which indicated that the error of DDs varied from 3.882 to 26.943, and the corresponding error of dates (between the observed and predicted dates) was 0 – 3 days. In rice-producing regions in northeastern China, farmers could use the results of the forecasting model to help make decisions for the effective control of the rice stem borer.

Key words: *Chilo suppressalis*; forecasting model; degree-days; trap catches

The rice stem borer (RSB), *Chilo suppressalis* (Walker) (Lepidoptera: Pyralidae), is one of the most serious rice borers in temperate and subtropical Asia. In most parts of Jilin, one of the northeastern provinces in China, there is only one generation of RSB a year. RSBs overwinter as fully grown larvae inside the rice roots in the soil at a depth of 2 – 5 cm and pupate in the spring; adults usually emerge from mid-May to early August. The pest population density tended to increase in recent years owing to changes in rice variety and cultural practices and higher temperatures, which had resulted in severe losses to rice farmers (Sheng *et al*., 2002). Farmers mainly depend on insecticides to control the pest, and the chemical treatment requires the timely prediction of the optimum dates corresponding to the brief period between egg hatch and initial entry of the larvae into the rice leafsheaths. Therefore, a reliable estimation of the start of adult emergence and flight peak is essential (Howse *et al*., 1998). Since the main three pheromonal components, (*Z*)-11-hexadecenal, (*Z*)-13-octadecenal and (*Z*)-9-hexadecenal, were identified from the female RSB (Nesbitt *et al*., 1975; Ohta *et al*., 1976; Tatsuki *et al*., 1983), pheromone traps have been widely used to monitor the RSB flight peak periods, population densities and infestation levels (Kanno *et al*., 1985; Tsuruta, 1987; Kondo and Tanaka, 1995; Kojima *et al*., 1996). Seasonal flight periods of RSB males have been reported from many areas in China, but information on the relationship between adult activity and DDs is lacking. The relationship between pheromone trap catches and DD accumulations, suitably transformed, had shown to be highly linear, which could help in the accurate estimation of emergence and treatment dates in many Lepidoptera pests (Riedl *et al*., 1976; Potter and Timmons, 1983; Ahmad and Ali, 1995; Judd and Gardiner, 1997; Del Tío *et al*., 2001). To help in the effective control of RSBs in northeastern China, we carried out a study to develop a reasonably accurate forecasting system for use in RSB management programs.

1 MATERIALS AND METHODS

The emergence and flight periods of the overwintering generation moths of RSB were monitored by

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pheromone traps in rice fields. This was carried out in 1999 – 2001 in Liuhe (42°15′N, 125°45′E) and 2002 – 2004 in Changchun (43°50′N, 125°18′E). Both regions are situated in Jilin province in northeastern China. The synthetic sex pheromone was a mixture of (*Z*)-11-hexadecenal, (*Z*)-13-octadecenal and (*Z*)-9-hexadecenal (41∶5∶4) (Jiao *et al*., 2005). The mixture (0.3 mg) and an antioxidant (0.3 mg BHT) were impregnated into a rubber septum. A water trap was used with a green plastic basin (18 cm × 24 cm base and 16 cm high) and set 0.5 m above the ground at the rice field boundary with three sticks placed in the rice fields from early May to late August in both regions every year. Ten traps were installed at a density of three per hectare in each region. The male moths caught by traps were counted and removed daily and, at the same time, water with detergent was added into the basins to maintain the traps' efficacy. Each rubber septum was renewed every three weeks.

Daily maximum and minimum temperatures were obtained from the weather stations nearby. Daily DD accumulations were calculated from 1 March by the single sine-wave method of Allen (1976), using a computer program to calculate the heat accumulation under a sine curve with the amplitude specified by each pair of daily maximum and minimum temperatures. In northeastern China, the lower and upper developmental thresholds of the RSB overwintering larvae are 12.9℃ and 30℃ (Li *et al*., 2000).

From the pheromone trap records, dates including the date of the first capture and those when the 10%, 50% and 90% capture flights occurring each year were determined. These data were associated with the accumulated DD that had occurred on that date. In addition, the three-year cumulative trapping data in Liuhe were plotted against a DD scale, for incorporation into the predictive model. Because of sigmoidal distribution of these data, DDs were transformed to $\log_{10}$ and cumulative catch percentages to probability units, or probits. A log-probit line was then fitted to the combined data by least-squares analysis.

Furthermore, in order to validate the predictive model, the actual dates and corresponding DDs of the first capture and 10%, 50%, and 90% captures of RSB males in Changchun were compared with the predicted dates and corresponding DD accumulations obtained from the Liuhe log-probit line.

2 RESULTS

The seasonal pheromone trap data for rice stem borer males in Liuhe over three years (Fig. 1) showed that the flights began in late May, peaked in early July, and ended in early August. Over three years in Changchun, flights began in mid-May, peaked in late June, and ended in early August (Fig. 2). It was warmer and RSB emergence there began earlier 0 – 16 days (average 8 days) in Changchun compared with that in Liuhe.

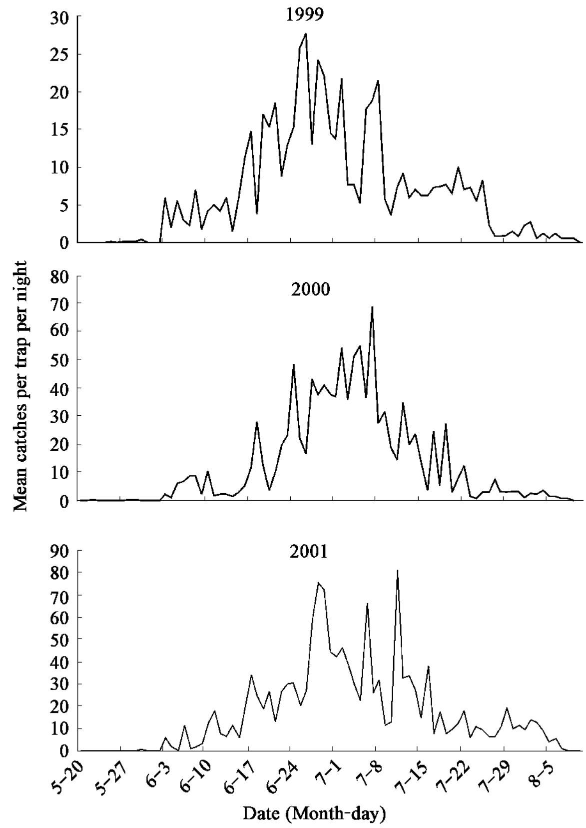

Fig. 1 Pheromone trap catches of male *Chilo suppressalis* in Liuhe rice fields from 1999 to 2001

The log-probit line and associated regression equation for cumulative male captures in Liuhe are presented in Fig. 3. A correlation coefficient of 0.9883 indicates a good fit of the calculated line to the data sets.

Dates and associated DD accumulations for first capture and 10%, 50% and 90% captures of RSB males are summarized in Table 1. The male flight began after average DD accumulations of 126.995 in Liuhe and 117.088 in Changchun. The predicted dates of 50% RSB male capture, the approximate target date for control, using the log-probit line in Changchun were 15, 26 and 25 June in 2002, 2003 and 2004, respectively. The actual dates of 50% RSB capture in Changchun were 17, 25 and 25 June and corresponding prediction errors were 2, 1 and 0 days. Average accumulated DDs to 50% cumulative catch, were 352.936 in Liuhe and 341.386 in Changchun.

Table 2 compares the predicted and observed values of DD accumulations of 10%, 50% and 90% male captures in Changchun in 2002, 2003 and 2004. The error of the DD accumulations varied from 3.882 to 26.943 and corresponding dates from 0 to 3 days.

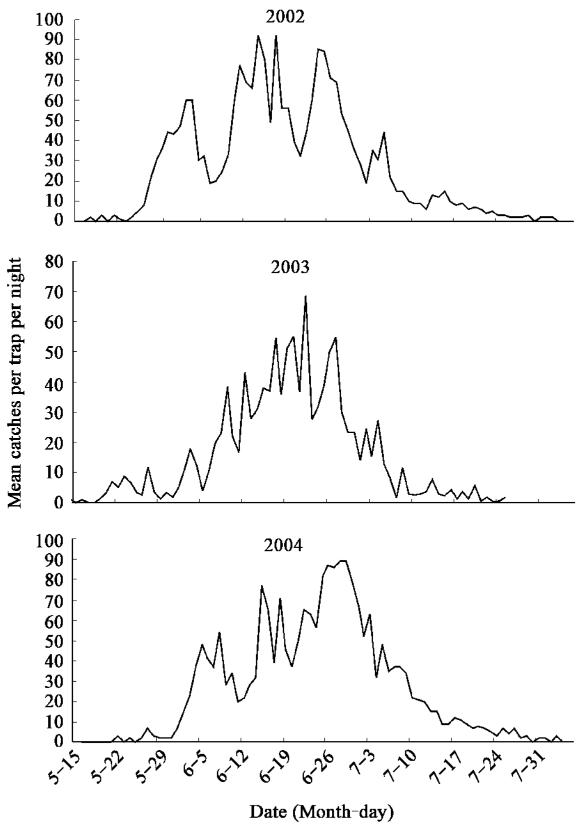

Fig. 2 Pheromone trap catches of male *Chilo suppressalis* in Changchun rice fields from 2002 to 2004

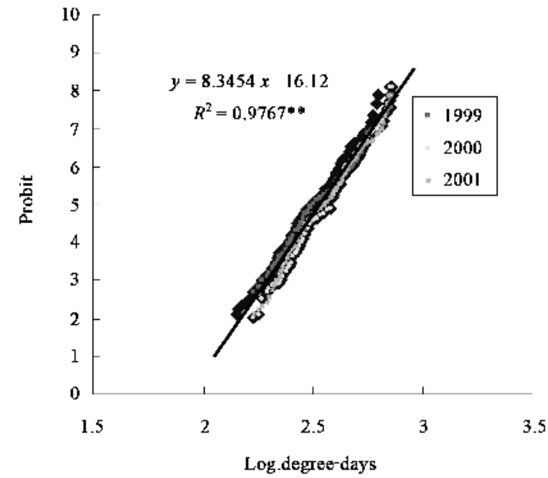

Fig. 3 The linear regression of trap catches of male *Chilo suppressalis* (Probit) versus degree-day accumulations (Log. degree-days) in Liuhe
** Significant at the 0.01 level.

3 DISCUSSION

The linear relationship between DD accumulations and pheromone trap catches of the male *Chilo suppressalis* was statistically significant. The correlation coefficient (r) of 0.9883 in the predictive model in the present study is significantly higher than those reported by others (Riedl *et al*., 1976; Potter and Timmons,

Table 1 Degree-days (DDs) from 1 March for cumulative seasonal captures of RSB males in pheromone traps in Jilin province, northeastern China

Site	Year	First capture		10% capture		50% capture		90% capture	
		Date		DDs		Date		DDs	
Liuhe	1999	May 25	130.057	June 15	225.972	June 29	308.36	July 20	509.123
	2000	May 22	122.833	June 23	270.405	July 6	387.897	July 19	500.213
	2001	May 28	128.094	June 20	246.681	July 4	362.552	July 20	483.151
	$\bar{x} \pm SE$	May 25	126.995 ± 2.157	June 19	247.686 ± 12.837	July 3	352.936 ± 23.458	July 20	497.496 ± 7.620
Changchun	2002	May 17	108.393	June 1	234.441	June 17	363.021	July 4	510.341
	2003	May 12	110.254	June 10	219.323	June 25	325.782	July 8	500.354
	2004	May 22	132.616	June 7	232.203	June 25	335.356	July 9	474.099
	$\bar{x} \pm SE$	May 17	117.088 ± 7.783	June 6	228.656 ± 4.711	June 22	341.386 ± 11.165	July 7	494.931 ± 10.808

Table 2 Comparison of predicted and observed values of degree-day accumulations corresponding to 10%, 50% and 90% captures in Changchun, northeastern China from 2002 to 2004

Year		10% capture	50% capture	90% capture
	Predicted values[a]	238.323	339.418	483.398
2002	Observed values[b]	234.441	363.021	510.341
	Error[c]	3.882	23.603	26.943
2003	Observed values	219.323	325.782	500.354
	Error	19.000	13.636	16.956
2004	Observed values	232.203	335.356	474.099
	Error	6.120	4.062	9.299

[a] Predicted values were the calculated values obtained from the log-probit line.
[b] Observed values were the actual values.
[c] Error was the difference between the predicted and observed values.

1983; Ahmad and Ali, 1995; Judd *et al*., 1997; Del Tío *et al*., 2001). This may be due to the different intervals between trap collections. In our study, the catches were collected daily, which may more accurately reflect the population dynamics. Taking into account that the speed of pest development is predominantly directed by temperature, once the predictive model is established, only the local DD accumulations rather than labor-intensive population monitoring are needed to determine the treatment dates. This predictive model could be used, at least in Jilin province, to predict the average dates of emergence or the cumulative trapped catches percentage for certain DD accumulations.

In general, the accuracy of the pest population monitoring methods, such as light and pheromone traps, is uncertain, because of the rain and wind. Before the model could be extended to other locations, more data derived from different locations and years need to be collected and validated. Del Tío *et al*. (2001) found that the linear correlations obtained from *Lobesia botrana* in the area of Jerez in Spain were rather different from those in Italy. It may be possible that there is an intraspecific genetic variability that is responsible for different biological responses to temperature.

Although the linear model could be used to predict RSB emergence and treatment dates, it should be noted that action can not be taken before the pest population density or the crop infestation level exceeds the control threshold. Jiao *et al*. (2004) estimated a control threshold of RSBs on the basis of pheromone trap catches and concluded that once the cumulative catch reaches 848 on the treatments dates, alternative control decisions could be made.

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用诱蛾量和有效积温模型预测东北越冬代水稻二化螟发生期

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摘要:在吉林省柳河县绿色稻米生产区,采用 1999~2001 年间 3 月 1 日后有效积温和水稻二化螟诱捕器诱蛾量数据,用线性模型探讨了当地有效积温和诱捕器诱蛾量之间的关系。由建立的线性模型确定越冬代水稻二化螟发蛾始盛期、高峰期和盛末期所需有效积温分别为 238.323、339.418 和 483.398 日·度。采用吉林长春稻区 2002~2004 年 3 年间数据比较模型预测值和观察值之间的差异,有效积温的误差值在 3.882~26.943 日·度之间,相应时间误差为 0~3 天。模型预测准确性较好,可用以及时指导大田防治。

关键词:二化螟;预测模型;有效积温;诱蛾量
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